CLAIMS

What is claimed is:

1. A network having a plurality of multicast connections, said network comprising:

an input stage comprising r_1 input switches, and n_1 inlet links for each of said r_1 input switches;

an output stage comprising r_2 output switches, and n_2 outlet links for each of said r_2 output switches; and

a middle stage comprising m middle switches, and each middle switch comprising at least one link (hereinafter "first internal link") connected to each input switch for a total of at least r_1 first internal links, each middle switch further comprising at least one link (hereinafter "second internal link") connected to each output switch for a total of at least r_2 second internal links;

wherein each multicast connection from an inlet link passes through at most two middle switches, and said multicast connection further passes to a plurality of outlet links from said at most two middle switches.

2. The network of claim 1, wherein $m \geq 2 * n_1 + n_2 - 1$.

3. The network of claim 2,

further is always capable of setting up said multicast connection by never changing path of an existing multicast connection, and the network is hereinafter "strictly nonblocking network".

4. The network of claim 1 further comprising a controller coupled to each of said input, output and middle stages to set up said multicast connection.

5. The network of claim 2 wherein said r_1 input switches and r_2 output switches are the same number of switches.

6. The network of claim 2 wherein said n_1 inlet links and n_2 outlet links are the same number of links and $n_1 = n_2 = n$, then $m \geq 3 * n - 1$.

7. The strictly nonblocking network of claim 3,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more strictly nonblocking networks.

8. The network of claim 1,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more networks.

9. A method for setting up one or more multicast connections in a network having an input stage having $n_1 * r_1$ inlet links and r_1 input switches, an output stage having $n_2 * r_2$ outlet links and r_2 output switches, and a middle stage having m middle switches, where each middle switch is connected to each of said r_1 input switches through r_1 first internal links and each middle switch further comprising at least one link connected to at most d said output switches for a total of at least d second internal links, wherein $1 \leq d \leq r_2$, said method comprising:

receiving a multicast connection at said input stage;

fanning out said multicast connection in said input stage into at most two middle switches to set up said multicast connection to a plurality of output switches among said r_2 output switches, wherein said plurality of output switches are specified as destinations of said multicast connection, wherein first internal links from said input switch to said at most two middle switches and second internal links to said destinations from said at most two middles switches are available.

10. A method of claim 9 wherein said act of fanning out is performed without changing any existing connection to pass through another middle switch.

11. A method of claim 9 wherein said act of fanning out is performed recursively.

12. A method for setting up one or more multicast connections in a network having an input stage having $n_1 * r_1$ inlet links and r_1 input switches, an output stage having $n_2 * r_2$ outlet links and r_2 output switches, and a middle stage having m middle switches, where each middle switch is connected to each of said r_1 input switches through r_1 first internal links and each middle switch further comprising at least one link connected to at most d said output switches for a total of at least d second internal links, wherein $1 \leq d \leq r_2$, said method comprising:

checking if at least a first subset of destination output switches of said multicast connection have available second internal links to a first middle switch; and

checking if a second middle switch has available second internal links to a second subset of destination output switches of said multicast connection.

wherein each destination output switch of said multicast connection is one of said first subset of destination output switches and said second subset of destination output switches.

13. The method of claim 12 further comprising:

checking if the input switch of said multicast connection has an available first internal link to said first middle switch and to said second middle switch.

14. The method of claim 12 further comprising:

prior to said checkings, checking if all the destination output switches of said multicast connection are available at said first middle switch.

15. The method of claim 12 further comprising:

repeating said checkings of available second internal links to another second subset of destination output switches for each middle switch other than said first and said second middle switches.

wherein each destination output switch of said multicast connection is one of said first subset of destination output switches and said second subset of destination output switches.

16. The method of claim 12 further comprising:

repeating said checkings of available second internal links to another first subset of destination output switches with each middle stage switch other than said first middle stage switch.

17. The method of claim 12 further comprising:

setting up each of said multicast connection from its said input switch to its said output switches through not more than two middle switches, selected by said checkings, by fanning out said multicast connection in its said input switch into not more than said two middle stage switches.

18. A method of claim 12 wherein any of said acts of checking and setting up are performed recursively.

19. A method of setting up a multicast connection through a three-stage network, said method comprising:

fanning out only one or two times in an initial stage.

20. The method of claim 19 further comprising:

fanning out any number of times in each of the remaining stages,

wherein said three-stage network includes said remaining stages and said initial stage.

21. The method of claim 19 further comprising:

repeating said acts of fanning out with a plurality of portions of each of said stages.

22. The method of claim 19 further comprising:

recursively performing said act of fanning out.

23. The method of claim 19 wherein:

a remaining stage immediately following said initial stage comprises internal links that are at least two times the total number of inlet links of said initial stage.

24. The method of claim 19 wherein:

said initial stage comprises a plurality of first switches, and a plurality of inlet links connected to each said first switch; and

a remaining stage immediately following said initial stage comprises a plurality of second switches, that are at least double the number of inlet links of each first switch and each second switch comprises a plurality of internal links at least equal in number to the number of first switches in said initial stage.

25. A network comprising:

an input stage comprising N_1 or $n_1 * r_1$ inlet links and r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$, said n_1 inlet links for receiving multicast connections;

an output stage comprising N_2 or $n_2 * r_2$ outlet links and r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$, said n_2 outlet links for transmitting said received connections; and

a middle stage having m middle switches, and each middle switch comprising at least one link connected to each input switch for a total of at least r_1 first internal links and each middle switch further comprising at least one link connected to at most d output switches for a total of at least d second internal links, wherein $1 \le d \le r_2$,

said initial stage having multicast connections with a fan-out of one or two.

26. The network of claim 25 further comprising:

said multicast connections having a fan-out of one or more in said middle stage.

27. The network of claim 25 further comprising:

said multicast connections having a fan-out of one or more in said output stage.

28. A network having a plurality of multicast connections, said network comprising:

an input stage comprising r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$;

an output stage comprising r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$; and

a middle stage comprising m middle switches, and each middle switch comprising at least one link connected to each input switch for a total of at least r_1 first internal links; each middle switch further comprising at least one link connected to each output switch for a total of at least r_2 second internal links,

wherein each multicast connection from an inlet link passes through at most three middles switches, and said multicast connection further passes to a plurality of outlet links from said at most two middle switches.

29. The network of claim 28, wherein $m \geq 3 * n_1 + n_2 - 1$,

30. The network of claim 29,

further is always capable of setting up said multicast connection by never changing path of an existing multicast connection, and the network is hereinafter "strictly nonblocking network".

31. The network of claim 28 comprising a controller in communication with said input, output and middle stages to set up said multicast connection.

32. The network of claim 29 wherein said r_1 input switches and r_2 output switches are the same number of switches.

33. The network of claim 29 wherein said n_1 inlet links and n_2 outlet links are the same number of links and $n_1 = n_2 = n$, then $m \geq 4 * n - 1$.

34. The strictly nonblocking network of claim 30,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more strictly nonblocking networks.

35. The network of claim 28,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more networks.

36. A method for setting up one or more multicast connections in a network having an input stage having $n_1 * r_1$ inlet links and r_1 input switches, an output stage having $n_2 * r_2$ outlet links and r_2 output switches, and a middle stage having m middle switches, where each middle switch is connected to each of said r_1 input switches through r_1 first internal links and each middle switch further comprising at least one link connected to at most d said output switches for a total of at least d second internal links, wherein $1 \le d \le r_2$, said method comprising :

receiving a multicast connection at said input stage;

fanning out said multicast connection in said input stage into at most three middle switches to set up said multicast connection to a plurality of output switches among said r_2 output switches of said multicast connection, wherein said plurality of output switches are specified as destinations of said multicast connection, wherein first internal links from said input switch to said at most three middle switches and second internal links to said destinations from said at most three middle switches are available.

37. A method of claim 36 wherein said act of fanning out is performed without changing any existing connection to pass through another middle switch.

38. A method of claim 36 wherein said act of fanning out is performed recursively.

39. A method for setting up one or more multicast connections in a network having an input stage having $n_1 * r_1$ inlet links and r_1 input switches, an output stage having $n_2 * r_2$ outlet links and r_2 output switches, and a middle stage having m middle switches, where each middle switch is connected to each of said r_1 input switches through r_1 first internal links and each middle switch further comprising at least one link connected to at most d said output switches for a total of at least d second internal links, wherein $1 \le d \le r_2$, said method comprising :

checking if all the destination output switches of said multicast connection have available second internal links from at most three middle switches.

40. The method of claim 39 further comprising:

checking if the input switch of said multicast connection has available first internal links to at most said three middle switches.

41. The method of claim 39 further comprising:

repeating said checkings of available second internal links to all said destination output switches for all the other combinations of at most three middle switches.

42. The method of claim 39 further comprising:

setting up each of said connection from its said input switch to its said output switches through at most said three middle switches, selected by said checkings, by fanning out said multicast connection in its said input switch into at most said three middle stage switches;

43. A method of claim 39 wherein any of said acts of checking and setting up are performed recursively.

44. A method of setting up a multicast connection through a three-stage network, said method comprising:

fanning out at most three times in an initial stage.

45. The method of claim 44 further comprising:

fanning out any number of times in each of the remaining stages,

wherein said three-stage network includes said remaining stages and said initial stage.

46. The method of claim 44 further comprising:

repeating said acts of fanning out with a plurality of portions of each said stages.

47. The method of claim 44 further comprising:

recursively performing said act of fanning out.

48. The method of claim 44 wherein:

a remaining stage immediately following said initial stage comprises internal links that are at least three times the total number of inlet links of said initial stage.

49. The method of claim 44 wherein:

said initial stage comprises a plurality of first switches, and plurality of inlet links connected to each said first switch; and

a remaining stage immediately following said initial stage comprises a plurality of second switches, that are at least three times the number of inlet links of each first switch and each second switch comprises a plurality of first internal links at least equal in number to the number of first switches in said initial stage.

50. A network comprising:

an input stage comprising N_1 or $n_1 * r_1$ inlet links and r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$, said n_1 inlet links for receiving connection connections;

an output stage comprising N_2 or $n_2 * r_2$ outlet links and r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$, said n_2 outlet links for transmitting said received connections; and

a middle stage having m middle switches, and each middle switch has at least one link connected to each input switch for a total of at least r_1 first internal links and each middle switch further comprising at least one link connected to at most d output switches for a total of at least d second internal links, wherein $1 \le d \le r_2$,

said initial stage having multicast connections with a fan-out of at most three.

51. The network of claim 50 further comprising:

said multicast connections having a fan-out of one or more in said middle stage.

52. The network of claim 50 further comprising:

said multicast connections having a fan-out of one or more in said output stage.

53. A network having a plurality of multicast connections, said network comprising:

an input stage comprising r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$;

an output stage comprising r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$; and

a middle stage comprising m middle switches, and each middle switch comprising at least one link connected to each input switch for a total of at least r_1 first internal links; each middle switch further comprising at least one link connected to each output switch for a total of at least r_2 second internal links, for $x \geq 1$,

wherein each multicast connection from an inlet link passes through at most x middles switches, and said multicast connection further passes to a plurality of outlet links from said at most x middle switches.

54. The network of claim 53, wherein $m \geq x * n_1 + n_2 - 1$, for $x \geq 2$.

55. The network of claim 54,

further is always capable of setting up said connection by never changing path of a previously set up multicast connection, and the network is hereinafter "strictly nonblocking network".

56. The network of claim 53 comprising a controller in communication with said input, output and middle stages to set up said multicast connection.

57. The network of claim 54 wherein said r_1 input switches and r_2 output switches are the same number of switches.

58. The network of claim 54 wherein said n_1 inlet links and n_2 outlet links are the same number of links and $n_1 = n_2 = n$, then $m \geq (x+1) * n - 1$.

59. The strictly nonblocking network of claim 55,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more strictly nonblocking networks.

60. The network of claim 53,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more networks.

61. A method for setting up one or more multicast connections in a network having an input stage having $n_1 * r_1$ inlet links and r_1 input switches, an output stage having $n_2 * r_2$ outlet links and r_2 output switches, and a middle stage having m middle switches, where each middle switch is connected to each of said r_1 input switches through r_1 first internal links and each middle switch further comprising at least one link connected to at most d said output switches for a total of at least d second internal links, wherein $1 \le d \le r_2$, for $x \ge 2$, said method comprising:

receiving a multicast connection at said input stage;

fanning out said multicast connection in said input stage into at most x middle switches to set up said multicast connection to a plurality of output switches among said r_2 output switches, wherein said plurality of output switches are specified as destinations of said multicast connection, wherein first internal links from said input switch to said at most x middle switches and second internal links to said destinations from said at most x middles switches are available.

62. A method of claim 61 wherein said act of fanning out is performed without changing any existing connection to pass through another middle switch.

63. A method of claim 61 wherein said act of fanning out is performed recursively.

64. A method for setting up one or more multicast connections in a network having an input stage having $n_1 * r_1$ inlet links and r_1 input switches, an output stage having $n_2 * r_2$

outlet links and r_2 output switches, and a middle stage having m middle switches, where each middle switch is connected to each of said r_1 input switches through r_1 first internal links and each of said r_2 said output switches through r_2 second internal links, for $x \geq 2$, said method comprising:

checking if all the destination output switches of said multicast connection have available second internal links from at most x middle switches.

65. The method of claim 64 further comprising:

checking if the input switch of said multicast connection has an available first internal links to said at most x middle switches.

66. The method of claim 64 further comprising:

repeating said checkings of available second internal links to all said destination output switches for all the other combinations of at most x middle switches.

67. The method of claim 64 further comprising:

setting up each of said connection from its said input switch to its said output switches through at most x said middle switches, selected by said checkings, by fanning out said mutlicast connection in its said input switch into at most said x middle stage switches.

68. A method of claim 64 wherein any of said acts of checking and setting up are performed recursively.

69. A method of setting up a multicast connection through a three-stage network, for $x \geq 2$, said method comprising:

fanning out at most x times in an initial stage.

70. The method of claim 69 further comprising:

fanning out any number of times in each of the remaining stages,

wherein said three-stage network includes said remaining stages and said initial stage.

71. The method of claim 69 further comprising:

repeating said acts of fanning out with a plurality of portions of each of said stages.

72. The method of claim 69 further comprising:

recursively performing said act of fanning out.

73. The method of claim 69 wherein:

a remaining stage immediately following said initial stage comprises internal links that are at least x times the total number of inlet links of said initial stage.

74. The method of claim 69 wherein:

said initial stage comprises a plurality of first switches, and plurality of inlet links connected to each said first switch; and

a remaining stage immediately following said intial stage comprises a plurality of second switches that are at least x times the number of inlet links of each first switch and each second switch comprises a plurality of first internal links at least equal in number to the number of first switches in said initial stage.

75. A network comprising:

an input stage comprising N_1 or $n_1 * r_1$ inlet links and r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$, said n_1 inlet links for receiving connection connections;

an output stage comprising N_2 or $n_2 * r_2$ outlet links and r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$, said n_2 outlet links for transmitting said received connections; and

a middle stage having m middle switches, and each middle switch has at least one link connected to each input switch for a total of at least r_1 first internal links and each middle switch further comprising at least one link connected to at most d said output switches for a total of at least d second internal links, wherein $1 \leq d \leq r_2$,

said initial stage having multicast connections with a fan-out of at most x, for $x \geq 2$.

76. The network of claim 75 further comprising:

said multicast connections having a fan-out of one or more in said middle stage.

77. The network of claim 75 further comprising:

said multicast connections having a fan-out of one or more in said output stage.

78. A network having a plurality of multicast connections, said network comprising:

an input stage comprising r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$;

an output stage comprising r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$; and

a middle stage comprising m middle switches, and each middle switch comprising at least one link connected to each input switch for a total of at least r_1 first internal links; each middle switch further comprising at least one link connected to each output switch for a total of at least r_2 second internal links;

wherein $m \geq \sum_{i=1}^{P}(x_i * a_i + n_1 - 1)$, where $\sum_{i=1}^{P} a_i = n_1 + n_2$ and $x_1, x_2, ..., x_p \geq 1$;

wherein, for $1 \leq i \leq p$, multicast connections from a_i inlet links of each input switch pass through at most x_i middles switches.

79. The network of claim 78, where $x_1, x_2, ..., x_p \geq 2$,

further is capable of setting up said connection by never changing path of a previously set up multicast connection, and the network is hereinafter "strictly nonblocking network".

80. The network of claim 78 comprising a controller in communication with said input, output and middle stages to set up said multicast connection.

81. The network of claim 78 wherein said r_1 input switches and r_2 output switches are the same number of switches.

82. The network of claim 78 wherein said n_1 inlet links and n_2 outlet links are the same number of links and $n_1 = n_2 = n$.

83. The strictly nonblocking network of claim 79,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more strictly nonblocking networks.

84. The network of claim 78,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more networks.

85. A network having a plurality of multicast connections, said network comprising:

an input stage comprising r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$;

an output stage comprising r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$; and

a middle stage comprising m middle switches, and each middle switch comprising at least one link connected to each input switch for a total of at least r_1 first internal links; each middle switch further comprising at least one link connected to at most d said output switches for a total of at least d second internal links, wherein $1 \le d \le r_2$,

wherein each multicast connection from an inlet link passes through at most one or two middles switches, and said multicast connection further passes a plurality of outlet links from said at most two middle switches.

86. The network of claim 85, wherein $m \ge 2 * n_1 + n_2 - 1$,

87. The network of claim 86,

further is always capable of setting up said connection by never changing path of a previously set up multicast connection, and the network is hereinafter "strictly nonblocking network".

88. The network of claim 85 comprising a controller in communication with said input, output and middle stages to set up said multicast connection.

89. The network of claim 86 wherein said r_1 input switches and r_2 output switches are the same number of switches.

90. The network of claim 86 wherein said n_1 inlet links and n_2 outlet links are the same number of links and $n_1 = n_2 = n$, then $m \geq 3 * n - 1$.

91. The strictly nonblocking network of claim 87,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more strictly nonblocking networks.

92. The network of claim 85,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more networks.

93. A network having a plurality of multicast connections, said network comprising:

an input stage comprising r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$;

an output stage comprising r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$; and

a middle stage comprising m middle switches, and each middle switch comprising at least one link connected to each input switch for a total of at least r_1 first internal links; each middle switch further comprising at least one link connected to at

most d said output switches for a total of at least d second internal links, wherein $1 \leq d \leq r_2$,

wherein each multicast connection from an inlet link passes through at most three middles switches, and said multicast connection further passes a plurality of outlet links from said at most three middle switches.

94. The network of claim 93, wherein $m \geq 3 * n_1 + n_2 - 1$,

95. The network of claim 94,

further is always capable of setting up said connection by never changing path of a previously set up multicast connection, and the network is hereinafter "strictly nonblocking network".

96. The network of claim 93 comprising a controller in communication with said input, output and middle stages to set up said multicast connection.

97. The network of claim 94 wherein said r_1 input switches and r_2 output switches are the same number of switches.

98. The network of claim 94 wherein said n_1 inlet links and n_2 outlet links are the same number of links and $n_1 = n_2 = n$, then $m \geq 4 * n - 1$.

99. The strictly nonblocking network of claim 95,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more strictly nonblocking networks.

100. The network of claim 93 ,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more networks.

101. A network having a plurality of multicast connections, said network comprising:

an input stage comprising r_1 input switches and n_1 inlet links for each of said r_1 input switches, and $N_1 = n_1 * r_1$;

an output stage comprising r_2 output switches and n_2 outlet links for each of said r_2 output switches, and $N_2 = n_2 * r_2$; and

a middle stage comprising m middle switches, and each middle switch comprising at least one link connected to each input switch for a total of at least r_1 first internal links; each middle switch further comprising at least one link connected to at most d output switches for a total of at least d second internal links, wherein $1 \le d \le r_2$, for $2 \le x \le r_2$,

wherein each multicast connection from an inlet link passes through at most x middles switches, and said multicast connection further passes a plurality of outlet links from said at most x middle switches.

102. The network of claim 101, wherein $m \ge x * n_1 + n_2 - 1$.

103. The network of claim 102,

further is always capable of setting up said connection by never changing path of a previously set up multicast connection, and the network is hereinafter "strictly nonblocking network".

104. The network of claim 101 comprising a controller in communication with said input, output and middle stages to set up said multicast connection.

105. The network of claim 102 wherein said r_1 input switches and r_2 output switches are the same number of switches.

106. The network of claim 102 wherein said n_1 inlet links and n_2 outlet links are the same number of links and $n_1 = n_2 = n$, then $m \ge (x+1) * n$.

107. The strictly nonblocking network of claim 103,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more strictly nonblocking networks.

108. The network of claim 101,

wherein each of said input switches, or each of said output switches, or each of said middle switches further recursively comprise one or more networks.

109. A network comprising a plurality of input subnetworks, a plurality of middle subnetworks, and a plurality of output subnetworks, wherein at least one of said input subnetworks, said middle subnetworks and said output subnetworks recursively comprise:

an input stage comprising r_1 input switches and n_1 inlet links for each of said r_1 input switches;

an output stage comprising r_2 output switches and n_2 outlet links for each of said r_2 output switches; and

a middle stage, said middle stage comprising m middle switches, and each middle switch comprising at least one link (hereinafter "first internal link") connected to each input switch for a total of at least r_1 first internal links, each middle switch further comprising at least one link (hereinafter "second internal link") connected to each output switch for a total of at least r_2 second internal links, for $x \leq 2$;

wherein each multicast connection from an inlet link passes through at most x middle switches, and said multicast connection further passes to a plurality of outlet links from said at most x middle switches.

add B10